

General Atomics - Aeronautical Systems Inc.



Presented to:
NTSB UAS Safety Forum
29, 30 April 2008

General Atomics Aeronautical Systems, Inc.

- **Aircraft Systems Group**

- Designs, develops, produces, and supports unmanned aircraft systems
 - Aircraft
 - Ground Control Stations
 - Support equipment
 - Logistics and personnel support
 - Integration of all sensors

- **Reconnaissance Systems Group**

- Designs, develops, produces, and supports sensor systems for unmanned and manned aircraft
 - Lynx SAR
 - CLAW sensor control
 - Integration of sensors in manned aircraft



General Atomics Aeronautical Systems, Inc.



Manufacturing Facility – Rancho Bernardo
San Diego, California



Manufacturing Facility – Rancho Bernardo
San Diego, California



Flight Operations and Training Facility
El Mirage, California



Stores/Parts Facility – Thornmint
San Diego, California



Composite Manufacturing Facility – Sabre Springs
San Diego, California



Flight Operations and Training Facility
Gray Butte – Palmdale, California



Building #3 – Rancho Bernardo
San Diego, California



Reconnaissance Group Facility – Sabre Springs
San Diego, California



Research and Development Facility
Adelanto, California

Family of Aircraft – Persistent Awareness: Land & Sea



PREDATOR B/Reaper
Hunter Killer/
Maritime Surveillance



Mariner
Long Endurance Maritime Surveillance



SKY WARRIOR
U.S. Army Ground Troop Support



ALTAIR
High Altitude Scientific Research



I-GNAT EXTENDED RANGE
U.S. Army Ground Troop Support



I-GNAT
Long Endurance



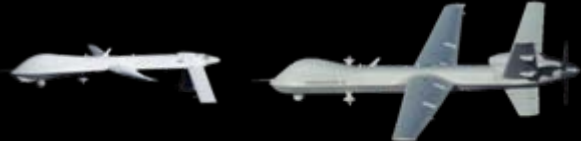
PREDATOR
Armed Surveillance

- Established 1990
- Delivered 260+ aircraft

Customer Base



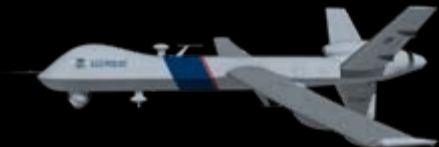
Predator, Predator B (Reaper)



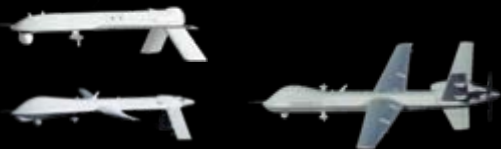
I-GNAT ER, Sky Warrior A & O
Sky Warrior (ER/MP)



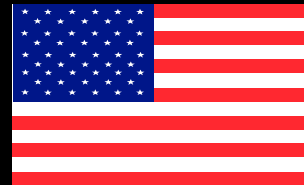
Predator B



GNAT-750, Predator,
Predator B



Altus, Altair, Predator B



GNAT-750, I-GNAT,
Predator B



Predator B (Reaper)



Predator



GNAT-750, I-GNAT



Predator



Wingspan:	55 ft
Length:	27 ft
Max altitude:	25,000 ft
Max endurance:	40 hr

Max air speed:	120 KIAS
Max gross takeoff weight:	2,300 lb
Payload capacity:	450 lb internal 300 lb external
Payloads:	<ul style="list-style-type: none">• EO/IR camera system• SAR• 2 Hellfire missiles

Army I-GNAT-ER / Sky Warrior Alpha



- 17 produced
- 13 are in combat
- Two aircraft have exceeded 10,000 total flight hours

Sky Warrior – Block 0 (Deployed March 2008)



Wingspan:	56 ft	Max air speed:	135+ KTAS
Length:	28 ft	Max gross takeoff weight:	3,200 lb
Max altitude:	29,000 ft	Payload capacity:	575 lb internal 500 lb external
Max endurance:	30+ hr	Payloads:	<ul style="list-style-type: none">• EO/IR camera system• SAR• 4 Hellfire missiles• Communications relay

ER/MP Sky Warrior Block 1 Features



- **Differences from Predator**

- 30% increase in GTOW
- Four HELLFIRE missiles
- Heavy fuel engine
- Triple redundant avionics & flight controls
- Dual redundant flight control surfaces
- Dual 5KW alternators (10KW power available)
- Auto takeoff & land (dual systems)
- TCDL LOS communications
- TCDL air data relay communications
- De-icing
- One system GCS

Predator B/MQ-9 Reaper

Acquired by the U.S. Air Force, U.S. Navy, Department of Homeland Security, NASA, the Royal Air Force, and others



Wingspan:	66 ft	Max air speed:	240+ KTAS
Length:	36 ft	Max gross takeoff weight:	10,500 lb
Max altitude:	50,000+ ft	Payload capacity:	850 lb internal 3,000 lb external on 7 hardpoints
Max endurance:	30+ hr	Payloads:	<ul style="list-style-type: none">• EO/IR camera system• SAR• ESM• Multiple weapons capability• Multi-mode 360° Maritime surface search radar

Predator, Warrior, and Predator B Comparison



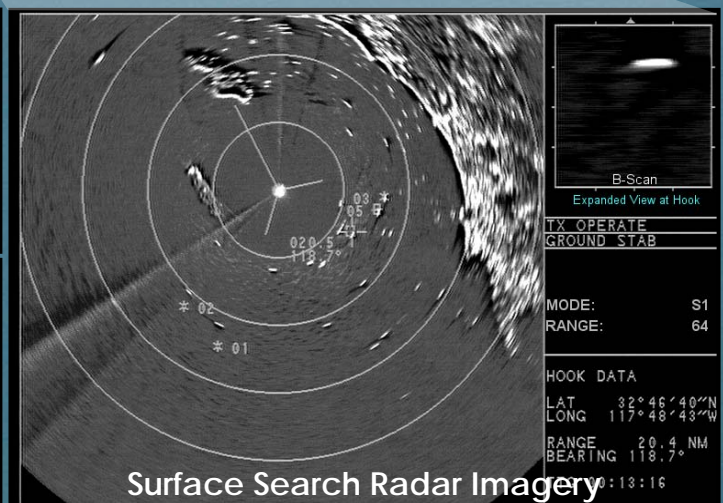
	Predator	Sky Warrior	Predator B
GTOW	2,300 lb	3,200 lb growth to 3,600	10,500 lb
Power	105 HP	135 HP	900 HP
Maximum Altitude	25,000 ft	29,000 ft	50,000+ ft
Maximum Speed	120 KTAS	135 KTAS	240 KTAS
Fuel	600 lb	580 lb	4,000 lb
Payload Nose	450 lb	575 lb	850 lb
Payload Wing	250 lb	500 lb	3,000 lb
Endurance	40 hr	31 hr	30+ hr

Current Operations - Warfighting



- Multiple orbits/CAPs per day supporting Southwest Asia operations
- USAF Predators are each flying 20-23 hour missions per day
- USA I-GNAT ER/Warrior Alpha each flying 17-20 hour missions per day
- Predators logging over 17,000 hours/month

Current Operations - Maritime



Current Operations – Research / Civil Application



Flight Summary

- CY-06 GA-ASI aircraft flew
 - 80,000 hours
 - 4,500 combat missions
- CY-07
 - 130,000 hours (50% growth)
 - 10,000 combat missions

***Predator aircraft have logged over 450,000 flight hours
> 360,000 combat flight hours***

Flight Summary



Every second of every day, 20
Predator series aircraft are
airborne worldwide

Airworthiness

- **Demonstrated Airworthiness via FAA UAS Experimental Certification Standards – FAA Order 8130.34**
 - Altair
 - Sky Warrior
 - Predator B
- **Demonstrated Airworthiness via DoD MIL-HDBK-516 (USN/USA/USAF)**
 - I-GNAT/ER
 - Predator
 - Predator B
 - Sky Warrior

Airworthiness – Predator B

Predator B Special Airworthiness
Certificate (Experimental) Briefing
23-24 Oct, 2007



The data contained in this presentation shall not be disclosed to the Government and shall not be duplicated, used, or disclosed in whole or in part for any purpose other than to evaluate the Predator B system for an FAA EASA Certification. This restriction does not limit the Government's right to use the data contained in the data if it is obtainable from another source without restriction.



**Received FAA COA –
Feb '06**

Agenda – Predator B FAA Safety Brief

Program Overview System Design

- Airframe
- Structures
- Propulsion
- Datalinks
- Electrical Power
- Avionics
- Flight Controls
- Performance
- Software Approach
- Ground Control Station
- Payloads

Safety

- System Safety Assessment
- Containment

Operations and Training

- Flight Operations
- Flight Crew Training
- Maintenance, Inspection, Training

**Received FAA Airworthiness
Certification – April '08**

Airworthiness – Predator B

Redundant Control Module (RCM)

Processing center of flight control system
Triple redundant flight computer architecture

Universal Asynchronous RS-422 Bus (UARB)

Dual redundant communication network for all flight critical nodes

“Smart” Servo Actuators

Microcontroller based design with dual UARB interface

Redundant Flight Surfaces

4 flaps, 4 ailerons, 4 ruddervators, 1 rudder

Honeywell Digital Electronic Engine Control (DEEC)

Engine sensor feedback (DEEC mode only)
ARINC 429 interface

Engine & Fuel Interface Unit (EFIU)

Engine sensor feedback (DEEC and b/u mode)
Dual UARB interface

Honeywell TPE331-10YGD-514GA turboprop engine

Engine family has a long history of use in aviation applications

TPE331 engines have over 100 million hours of service

Triplex Embedded GPS/INS (EGI) Units

Honeywell H-764 with embedded Trimble Force 5 GPS receiver
Redundant data interfaces to flight computers in RCM
Each EGI connected to dedicated GPS antenna

Triplex Air Data Sensor Sets

3 heated pitots, 6 heated static ports
6 Precision Pressure Transducers (PPT)

Alpha/Beta/OAT Probe

Alpha/Beta: vanes connected to potentiometers
OAT: Solid state sensor

Nose Cameras with Heated Lenses

1 daylight camera, 1 long wavelength IR camera

Ice Detector

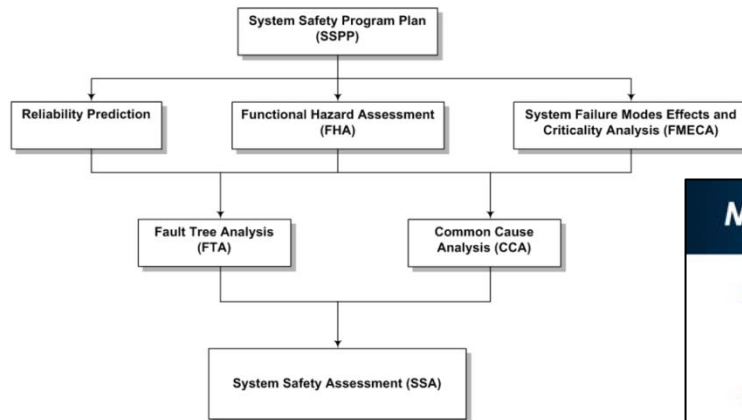
Magnetostrictive probe type from Goodrich

Architecture

3 Flight Computer Assemblies (FCA)
2 vote processing circuits on Vote Processor Assembly
2 LOS Datalink Processor Assemblies
1 Interface Processor Assembly (IPA)

Airworthiness Safety Case – Predator B

System Safety Process for USAF MQ-9



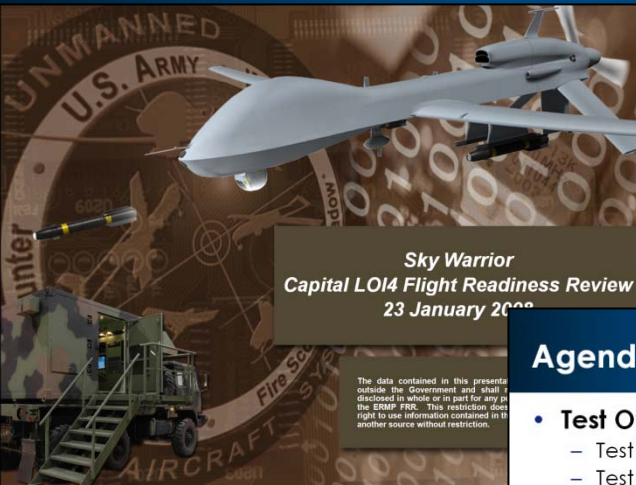
Conducted by GA-ASI

MQ-9 System Safety Tasks

- **System Safety Program Plan (SSPP)**
 - Outline process to be used for System Safety Program
 - Defines safety requirements
- **System Reliability Prediction Model**
 - Contains Predator B Aircraft and GCS Line Replaceable Units (LRUs)
- **Functional Hazard Assessment (FHA)**
 - Preliminary List of Hazards identified
 - Catastrophic and Critical cases from ICC
 - Includes Marginal and Negligible cases
- **Fault Tree Analysis (FTA)**
 - Preliminary fault tree for top events completed
 - Updating and expanding on FTAs for MQ-9 SDD design
- **Failure Modes Effects and Criticality Analysis (FMECA)**
 - Broken down to sub-system level
 - Identifies failures and effects within sub-system
 - Analysis at the card level is the next step for SDD

Item no.	ASI Number	Document Title
1	ASI-00947	System Safety Program Plan
2	Not Assigned	System Functional Description
3	ASI-01134	Functional Hazard Assessment
4	ASI-01192	Fault Tree Analysis
5	ASI-01132	System Safety Assessment Summary
6	Not Assigned	FMECA Work Book for MQ-9 UAV System Interim Combat Capability (ICC)

Airworthiness – Sky Warrior



Received FAA Airworthiness Certification – May '07

Agenda

- **Test Overview**
 - Test Objectives
 - Test Status
 - Flight Test Planning
 - Crew Qualifications/Manuals
 - Range Requirements
 - Stoplight Chart
- **Sub-system Test Results**
 - Testing Accomplished
 - Test Results
 - Open Issues
 - System Hardware
 - Software
 - FMECA Results
- **Risk Assessment**
- **Discussions**



2

Received FAA COA – Jan '08

AV Engineering Test Reports

- **AQS test reports delivered →**
- **Structures test reports posted to ShareIT**

ASI-01519	U.S. ARMY ERIMP SDD Warrior Block 1 Flight and Ground Loads Report
ASI-01520	Warrior Airworthiness Compliance Engine Performance
ASI-01532	Warrior Airworthiness Compliance - FAA Engine Certification
ASI-01536	Warrior Airworthiness Compliance Engine Oil Tank
ASI-01538	Warrior Airworthiness Compliance - Engine Oil Filter
ASI-01542	Warrior Airworthiness Compliance Engine Oil Pump
ASI-01544	Warrior Airworthiness Compliance Gearbox Oil Tank
ASI-01545	Warrior Airworthiness Compliance Gearbox Oil Lines and Fittings
ASI-01546	Warrior Airworthiness Compliance - Gearbox Oil Filter
ASI-01550	Warrior Airworthiness Compliance - Gearbox Oil Pump
ASI-01553	Warrior Airworthiness Compliance - Coolant Tank Test
ASI-01556	Warrior Airworthiness Compliance - Coolant Pump
ASI-01559	Warrior Airworthiness Compliance - Air Induction System
ASI-01565	Warrior Airworthiness Compliance - Engine Mount Attachment and Structure
ASI-01566	Warrior Airworthiness Compliance - Engine Mount
ASI-01568	Warrior Airworthiness Compliance - Powerplant Limitations
ASI-01575	Warrior Airworthiness Compliance - Maintainability- Design
ASI-01576	Warrior Airworthiness Compliance - Propulsion Environment
ASI-01577	Warrior Airworthiness Compliance - Propulsion Manufacturing Requirements
ASI-01580	Warrior Airworthiness Compliance - Propulsion Software Design Procedures
ASI-01579	Warrior Airworthiness Compliance - Engine Controller
ASI-01581	Warrior Airworthiness Compliance - Propeller Performance
ASI-01582	Warrior Airworthiness Compliance - Propeller System
ASI-01583	Warrior Airworthiness Compliance - Propeller Environment
ASI-01584	Warrior Airworthiness Compliance - Pitch Limit - Controls
ASI-01585	Warrior Airworthiness Compliance - Propeller Durability
ASI-01588	Warrior Airworthiness Compliance Fuel System Performance
ASI-01589	Warrior Airworthiness Compliance - Fuel Tanks Warrior UAV System
ASI-01592	Warrior Airworthiness Compliance - Fuel Filter
ASI-01594	Warrior Airworthiness Compliance - Fuel Injectors
ASI-01595	Warrior Airworthiness Compliance - Fuel Pressure Control Valve
ASI-01598	Warrior Airworthiness Compliance - Fuel System Lines and Fittings
ASI-01599	Warrior Airworthiness Compliance - Fuel System Drains
ASI-01601	Warrior Airworthiness Compliance - Fuel System Sensors
ASI-01604	Warrior Airworthiness Compliance - Alternator Performance
ASI-01605	Warrior Airworthiness Compliance - Alternator
ASI-01606	Warrior Airworthiness Compliance - Propulsion Power Cables
ASI-02249	ERIMP Block 1 Actual Weight Report
ASI-02294	Sky Warrior Brake Performance Analysis



39



Airworthiness – Sky Warrior

Design Features & Redundancy

- FADEC Redundant Engine Control Units (ECUs) with redundant sensor inputs
- Dual Fuel Tanks with Automatic Switching
- Dual Redundant Fuel Pumps
- Engine MTBIFSD of 35,000 Flight Hours
- Glide-back for safe recovery

Design Features & Redundancy

- Dual Redundant Electrical System (w/dual alternators, ARMs, and backup batteries)
- Dual Redundant 28VDC Power Busses
- Dual Network Junction Boards
- Dual Payload Power Distribution Modules

Design Features & Redundancy

- Triple Redundant Flight Computers
- Dual Aileron servos per wing (inboard & outboard)
- Triple Redundant INS/GPS and triple air data sensors
- Dual 1553 Buses and backup RS-422 bus
- Dual Redundant Electrical System (w/dual alternators, ARMs, backup batteries, and dual bus)
- Dedicated smart servos for each control surface
- Redundant PSO Workstations

Design Philosophy / Operational Impact

- **Evolved into:**
 - Redundant avionics
 - Certificated powerplants
 - Redundant flight controls
- **Instrument rated Pilots in comms with ATC**
- **Aircraft capable of IFR flight and IFR flight plans**
- **Resulting in:**
 - Operations over 5 continents, 5 oceans, many seas
 - Operations sequenced with manned commercial, general aviation, and military aircraft at international airports

Perspective

- **The good news**

- We have developed advanced, proven, airworthy unmanned aircraft systems with robust and redundant avionics and flight control systems
- We are delivering advanced 'capabilities' to the Warfighter. These unmanned aircraft systems are dramatically improving the efficiencies of air power
- We are providing a significant and positive effect in the fight against terror; home and abroad

Instrument rated pilots always in control

Perspective

- **The bad news**

- Continued development and delivery of these systems are being impacted by current regulatory constraints
 - Reduction of available Experimental Certifications
- Current operating limitations are inhibiting operator training in national air space
 - Prohibition against night operations
- NAS integration timeline measured in decades
 - Joint DoD - FAA effort a step in the right direction
 - Technical and Regulatory challenges
- This is all being tolerated in the middle of a very serious war on terror

Final Thoughts

- Aviation has touched all of our lives
- Innovation will continue and must be supported by government